Solar Wind Sputtering of Lunar Surface Materials: Role and Some Possible Implications of Potential Sputtering

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1. INTRODUCTION

Solar-wind induced sputtering of the lunar surface includes, in principle, both kinetic and potential sputtering. The role of the latter mechanism, however, in many focused studies has not been properly ascertained due partly to lack of data but can also be attributed to the assertion that the contribution of solar-wind heavy ions to the total sputtering is quite low due to their low number density compared to solar-wind protons.

Limited laboratory measurements show marked enhancements in the sputter yields of slow-moving, highly-charged ions impacting oxides. Lunar surface sputtering yields are important as they affect, e.g., estimates of the compositional changes in the lunar surface, its erosion rate, as well as its contribution to the exosphere as well as estimates of hydrogen and water contents.

Since the typical range of solar-wind ions at ~1 keV/amu is comparable to the thickness of the amorphous rim found on lunar soil grains, i.e. ~ few 10s nm, lunar simulant samples JSC-1A – AGGL are specifically enhanced to have such rims in addition to the other known characteristics of the actual lunar soil particles. However, most, if not all laboratory studies of potential sputtering were carried out in single crystal targets, quite different from the rim's amorphous structure. The effect of this structural difference on the extent of potential sputtering has not, to our knowledge, been investigated to date.

2. POTENTIAL vs. KINETIC SPUTTERING

The enhancements seen in the laboratory, e.g., [1], can be orders of magnitude for some surfaces and highly charged incident ions, but depends very sensitively on the properties of the impacted surface in addition to the fluence, energy and charge of the impacting ion. For oxides, potential sputtering yields are markedly enhanced and sputtered species, especially hydrogen and light ions, show marked dependence on both charge and dose.

The first of potential-sputtering data for lunar regolith analogs, albeit in preliminary form, were only recently presented [1]. These proof-of-principle measurements were made at Oak Ridge National Laboratory's Multi-charged Ion Research Facility (MIRF) using beams of 0.4 keV/amu H+, Ar+, Ar6+ and Ar9+ against samples of the lunar-simulant materials JSC-1A – AGGL. Enhanced (4-5 times) sputtering by Ar9+ compared to H+ has been seen for the mass range 10-20 amu.

3. IMPLICATIONS

For certain surface constituents, sputtering may preferentially change their stoichiometry and/or chemical composition. Depending on the sputtered species energy and charge state, some are lost to space while others become part of the lunar exosphere or return to its surface. The penetration depth (~10s of nm) of solar-wind ions are comparable to the thickness of the vapor-deposited layer found on lunar regolith particles. Hence, in general, the properties and composition of this layer (or rim) play critical roles in how the solar-wind ions couple to the lunar surface at the microscopic level.

As possible implications of this coupling and if potential sputtering were to contribute significantly [3] to the total sputter yield, the surface erosion rate [4] would increase proportionally leading to efficient mixing. Also, if sputtering selectivity is dominated by potential sputtering, simulated surface composition may turn out to have mineral depletions or enrichments that are different from results of studies based on kinetic sputtering alone.Other implications of potential sputtering relate to hydrogen and ice deposits on the moon.

4. REFERENCES

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